Argonne NATIONAL LABORATORY

Feature

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March 31, 2011

Argonne's CARIBU facility opens to study rare nuclei

Last week, a stream of highly unusual ions shot through a tiny nozzle at 76 million miles per hour—and CARIBU, a facility designed to study special nuclei normally only created in stars, officially opened for business.

Located at the U.S. Department of Energy's Argonne National Laboratory, CARIBU (for Californium Rare Isotope Breeder Upgrade) and its larger counterpart, ATLAS, are user facilities for nuclear physicists who study the particles that form the heart of atoms. CARIBU creates special beams that feed into ATLAS (Argonne Tandem-Linac Accelerator System), a superconducting accelerator that uses magnets to direct beams of isotopes at high speeds to experiments so that physicists can study them.

CARIBU's specialty is producing neutron-rich nuclei, exotic kinds of nuclei formed when extra neutrons are added to normal atoms. Extra neutrons make an atom unstable; the neutrons are liable to shoot off as the element decays into a more stable form. Since it takes an extraordinary force to create them, they are rarely seen on Earth and often only exist for seconds at a time.

Scientists think that these rare nuclei may hold the key to better understanding supernova explosions. Current scientific theory holds that most elements heavier than iron—including gold, silver, uranium, lead and copper—were created when stars exploded billions of years ago, producing neutron-rich nuclei that decayed into the stable, familiar elements we know today. Studying exotic nuclei helps scientists understand the forces that holds nuclei together and also provides greater insight into what happens inside nuclear reactors and nuclear fuel as it ages.

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"Nuclear scientists are increasingly interested in these nuclei, which are really different beasts," said Robert Janssens, head of Argonne's Physics Division. "That's why we began work on CARIBU: to provide access to these highly rare nuclei. Many of them have never been available for study. We are venturing off the edge of the map into new territory."

The recipe for a beam of neutron-rich nuclei begins with a thick, shielded cask holding a source of californium-252, a heavy, radioactive man-made element. The californium undergoes fission, similar to what happens inside a nuclear reactor. As the californium atoms split, they shoot apart into lighter elements—barium, xenon, cesium, etc.—that contain unusual numbers of neutrons.

These atoms now enter a device called the gas catcher, a helium-rich chamber, designed by Argonne physicist Guy Savard and his team, which helps preserve the nuclei in their unusual state. The helium atoms in the gas catcher serve as atomic flak jackets for the precious rare nuclei as they snatch up any loose electrons. Meanwhile, electric fields keep the valuable ions from sticking to the walls.

"It takes so much effort to produce these ions that each one is valuable," Savard explained. "You want to lose as few of them as possible along the way."

The gas catcher cools and channels the ions into a beam, which enters a separator: two large magnets that separate the various nuclei according to atomic mass. This process allows scientists to isolate particular isotopes to study.

Several more steps ensure that the beam, now whittled down to contain just one particular isotope, is in the correct charge state to be accelerated. The beam is then fed into ATLAS, the larger accelerator, or directed to another station where researchers study the mass and other properties of the neutron-rich nuclei.

"This machine is the best of its kind," Janssens said. Its efficiency is excellent, he explained—very few nuclei are lost while they are focused into a beam.

Experiments have already begun at CARIBU, Savard said, and will continue as the machine is fine-tuned for scientists to study the elusive nuclei that helped shape the universe.

The U.S. Department of Energy's Argonne National Laboratory seeks solutions to pressing national problems in science and technology. The nation's first national laboratory, Argonne conducts leading-edge basic and applied scientific research in virtually every scientific discipline. Argonne researchers work closely with researchers from hundreds of companies, universities, and federal, state and municipal agencies to help them solve their specific problems, advance America's scientific leadership and prepare the nation for a better future. With employees from more than 60 nations, Argonne is managed by UChicago Argonne, LLC for the U.S. Department of Energy's Office of Science.

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